

## **Towards Strategic Sustainability: the barriers and enablers of supplier involvement in product stewardship and clean technology strategies**

### **ABSTRACT**

Many of today's firms see sustainability as an exercise in reducing costs and minimizing risk. These organizations use pollution control or prevention techniques to limit the amount of waste in products or processes. By drawing on the Natural Resource Based View this paper calls for a more strategic approach to sustainability; one which moves beyond pollution prevention towards product stewardship and clean technology strategies. Specifically, the paper argues that suppliers should be involved in embedding product stewardship and clean technology strategies in a firm's new product development process to achieve a competitive advantage. To make this argument, the paper uses an in-depth case study of a high technology firm in the aerospace industry. The case study extends past the boundaries of the firm to include an examination of a supplier and customer, termed a triadic case study design. A triangulated data collection approach is used including forty-two semi-structured interviews, eight focus groups and secondary data. A theoretical contribution is made by determining how technological uncertainty affects supplier involvement in embedding product stewardship and clean technology strategies in new product development efforts. Practically, the paper advances a matrix to assist managers in deciding on appropriate types of supplier relationships when pursuing a product stewardship or clean technology strategy.

### **Keywords:**

Sustainability; Supply Chain Management; New Product Development

## 1. Introduction

Over the past few decades there has been increasing stakeholder pressure on organisations to improve their sustainable performance. These stakeholders make little distinction between a firm's internal operation and its supply base. Much of the literature on "Green" and "Sustainable" Supply Chain Management examines how firms implement pollution prevention techniques to minimize waste resulting in reduced costs rather than relying on expensive "end-of-pipe" pollution-control technology (Hart, 1995) i.e. short-term tactical as opposed to more long-term strategic investment decisions. This view is supported by a variety of studies; Klassen and Whybark (1999) show how a greater emphasis on pollution prevention technologies improves cost, delivery, flexibility, and environmental performance. Similarly, Christmann (2000) states the early use of pollution prevention technologies provides a cost advantage relative to competitors. Aragon-Correa and Sharma (2003) explain that proactive pollution prevention strategies enable an organization to align itself with changes in the business environment and lead to lower costs. Seuring and Muller's (2008) sustainable supply chain management framework includes: 1) stakeholder pressures; 2) supplier management for risks and performance and; 3) supply chain management for sustainable products. Carter and Rogers (2008) focus instead on organizational culture, transparency, and risk management. While no doubt informative this body of literature demonstrates a clear focus on how firms use sustainability as an exercise in a short-term cost and risk reduction rather than a sustainable strategic long-term focus.

The Natural Resource Based View (NRBV) argues firms need to move beyond the cost minimization focus of pollution prevention towards a more strategic approach to sustainability using product stewardship and clean technology strategies (Hart, 1995; 1997). Product stewardship strategies incorporate the views of external stakeholders in to product design and development to minimize pollution and waste over a products entire lifecycle.

Clean technology strategies call for more radical technologies that have the potential to revolutionize entire industries (Hart, 1997; Hart and Dowell, 2011). Hart and Dowell (2011) recently reported a robust body of literature exploring pollution prevention techniques but much less attention paid to how product stewardship and clean technology strategies could be employed to realise sustainable competitive advantage; this development was the key argument of NRBV.

Within the supply chain literature there is a growing body of work on supplier involvement in new product development (SINPD). Recently this literature has segregated supplier involvement into four levels of engagement including: no involvement, “white box” involvement where the supplier consults informally on design, “grey box” involvement where suppliers collaborate on design and development and finally “black box” involvement where the supplier is responsible for the design and development of entire components or subassemblies (see Petersen et al., 2005; Koufteros et al., 2007). Although this literature does stress the importance of involving suppliers in NPD efforts it focuses on the economic benefits paying limited attention to how suppliers can drive environmental performance improvements in the NPD process through strategies such as product stewardship and clean technology development.

This paper aims to fill this gap by posing the following research question: *“how can suppliers help firms embed product stewardship and clean technology strategies in the new product development cycle?”* To address this question we adopt an in-depth case study of a high technology firm in the aerospace sector. The case study extends past the boundaries of the firm to include a supplier and customer, termed a triadic case study design. This format provides an understanding of the role of different actors in helping or hindering the embedding of product stewardship and clean technology strategies in the NPD cycle.

The paper is divided into five sections. Section one is a literature review focusing on the use of NRBV and how SINPD can lead to the adoption of product stewardship and clean technology development approaches. Section two provides an overview of the research method including data collection and analysis techniques. The third section presents the findings from the case study including the enablers and inhibitors of supplier involvement in product stewardship and clean technology strategies. Section four provides a discussion of the findings and advances a model to assist managers when deciding on the appropriate type of supplier relationship when pursuing product stewardship and clean technology strategies. The final section discusses the theoretical and managerial implications of the study, the paper's limitations and future avenues of research.

## **2. Literature Review**

### *2.1 The Natural Resource Based View and Competitive Advantage*

The NRBV first espoused by Hart (1995) debates the inevitability of business being constrained by and dependent upon nature and suggests that future strategies should facilitate environmentally sustainable economic activities. The NRBV outlines three environmental capabilities that firms can develop to achieve competitive advantage: pollution prevention, product stewardship and clean technologies. Pollution prevention is considered a capability because its decentralized and tacit nature makes it difficult to observe in practice (causally ambiguous) and therefore hard to imitate (Hart, 1995; Dierickx and Cool, 1989; Lippman and Rumelt, 1982, Peteraf, 1993). While pollution prevention focuses on new capability building in a firm's internal operations, product stewardship addresses every activity of the supply chain from raw material sourcing, production and distribution to disposal or reuse. Product stewardship qualifies as a capability because it involves fluid communication across functions and organizational boundaries making it socially complex and therefore hard to imitate and substitute (Hart, 1995). Clean technologies reduce material and energy

consumption by utilizing technological advancements that provide for human needs without straining the planet's resources (Hart and Dowell, 2011). Clean technologies become a strategically important capability if they are distinct to the firm and difficult for the competition to imitate.

## *2.2 The role of technological uncertainty in Pollution Prevention, Product Stewardship and Clean Technology Strategies*

Hart (1997) made an explicit distinction between “greening” strategies (pollution prevention and product stewardship), which focus on incremental improvements to today's products and processes, and “beyond greening” strategies (clean technology) which are more radical in nature. “Greening” strategies foster continuous improvement rather than reinvention or fundamental change to technologies (Rooney, 1993; Hart and Milstein, 1999). Examples of pollution prevention techniques include changes in packaging to reduce waste and changes to manufacturing processes to minimize harmful effluents. As the firm is working from an established base of knowledge and expertise any incremental change to the new product tends to mean relatively low levels of technological uncertainty are present.

Product stewardship implies an organizational ability to not only coordinate functional groups within the firm, but also integrates the perspectives of key external stakeholders into decisions on product design and development (Welford, 1993). By involving key external stakeholders, such as suppliers, in NPD efforts the firm is able to minimize uncertainty by extending visibility up the supply chain. Close collaboration with suppliers allows the firm to proactively spot potential environmental issues in raw material sourcing, manufacturing or distribution. Furthermore, suppliers can bring in-depth knowledge and expertise of new environmentally friendly technologies and processes. Therefore, by drawing on supplier

insight firms are able to handle more moderate degrees of technological uncertainty during the development of new products.

While pollution prevention and product stewardship tend to favour incremental change, clean technologies require longer term re-thinking of industrial products and processes necessitating more radical advances in technology (Irwin and Hopper, 1992). Technological uncertainty is likely to have a significant effect on the development of clean technology capabilities because commercialization involves dealing with information that is uncertain, constantly evolving, and dynamically complex (Aragon-Correa & Sharma, 2003; Hart & Sharma, 2004; Hart and Dowell, 2011). For firms, this entails the organizational capacity to protect and nurture disruptive or leapfrog clean technologies, including those technologies that may eventually cannibalize parts of the existing core business (Hart and Dowell, 2011). The radical nature of clean technologies suggests an inherently high level of technological uncertainty being present during NPD projects.

### *2.3 Supplier Involvement in New Product Development*

The SI-NPD literature has reached different and sometimes contradictory findings around the importance of involving suppliers in the NPD process. Several studies have found early supplier involvement, often at the design stage, to be a critical factor in improved product performance (Bidault et al., 1998; Wasti and Liker, 1997; Swink, 1999). Ragatz et al. (1997) provided evidence that involving suppliers extensively and early reduced costs, improved quality and sped up time to market of new products. Similarly, Liker and Choi, (2004) indicated that early supplier involvement provided firms with accelerated time-to-market, improvements in innovativeness, reduced production costs, and enhanced quality. In the mid 2000's, the SI-NPD literature moved in a new direction, categorizing supplier involvement along a spectrum of engagement ranging from no involvement, to "white box", "grey box"

and finally “black box” integration (Petersen et al., 2005). Koufteros et al. (2007) found the effects of black-box integration on product innovation to be statistically non-significant, whilst the direct effect of supplier grey-box integration to be positive and statistically significant. This demonstrates that different degrees of supplier involvement can affect the outcomes of NPD projects. The aforementioned literature generally espouses the positive benefits of Supplier involvement in NPD projects. We begin to see greater disagreement when authors account for the role of technological uncertainty in NPD projects.

#### *2.4 SI-NPD and the role of technological uncertainty*

During the late 1990’s and 2000’s several authors began to include technological uncertainty into their analysis of NPD projects. Petersen et al. (2003) and Ragatz et al. (2002) suggested that supplier representation on NPD development teams is critical, especially in situations of high technological uncertainty. Song and Benedetto (2008) found that increased asset specific investments heightened the level of supplier involvement in the development of radical technologies which, in turn increased new product performance. In contrast, Eisenhardt and Tabrizi (1995) suggested that less supplier involvement might be necessary under conditions of high technological uncertainty. They found that technologically predictable projects showed positive effects of supplier involvement on development time however less predictable projects showed no significant effect of supplier involvement. Swink (1999) found supplier influence to be strongly associated with improved manufacturability but the correlation diminished in cases of high product “newness” or high technological uncertainty. Similarly, Primo and Amundson (2002) found that existing suppliers might be less important than new suppliers in conditions of high technological uncertainty. Finally, Phillips et al. (2006) suggest that involving existing direct suppliers in radical technology development may prove redundant as new complementary capabilities and technologies from outside the existing supply chain are required. As technological uncertainty appears to be such an

influential variable when involving suppliers in NPD projects it is considered as part of this study.

### **3. Research Method**

This paper uses an in-depth case study focussing on a high technology firm in the aerospace sector. The case study format was chosen because it offers in-depth data gathering and analysis. Using one case allows for the control of external effects. This type of industry is notoriously secret therefore it would have been very difficult to work with competitors and still have full access to deep 'dive' data. This method is supported by the literature. Voss et al. (2002) argue that case research has consistently been one of the most powerful research methods in Operations Management. Dyer and Wilkins (1991) argue that single case studies enable the researcher to capture in much more detail the context within which the phenomena under study occurs. Yin (2009) also supports the use of a single case design in certain situations including uniqueness and longitudinal research, these are both important criteria relating to this study.

#### *3.1 Unit of Analysis*

This paper reports on three technology development projects each representing one of the three environmental strategies of the NRBV: pollution prevention, product stewardship and clean technologies. The first technology project is the development of a material called Titanium Aluminide (TiAl) which is a combination of titanium and aluminium. This material has been incrementally developed by the case study company since the early 1990's. The lengthy development time and existing body of knowledge around the base metals means the TiAl project has relatively low levels of technological uncertainty in the eyes of the firm. TiAl is part of a pollution prevention strategy because it replaces a nickel alloy which includes rhenium, a rare-earth element, to increase heat resistance. Furthermore, nickel is a



carcinogen making it potentially harmful to engineers and mechanics during installation and disposal.

The case company as part of a product stewardship strategy is developing the second technology project, carbon composites. The case company has formed a joint venture to develop this material and the supplier has been involved since the design stage. The case company has benefited from the expertise and knowledge this supplier has accrued when developing carbon composites in other industries. By drawing on the supplier's experience the case company has been able to reduce uncertainty leading to relatively moderate degrees of technological uncertainty. Carbon composites provide environmental benefits because they are a lightweight alternative to the current material used and can remove up to eight hundred pounds of weight from the company's product. Lighter weight mean less fuel is burned and in turn less Carbon dioxide and nitric oxide emitted.

The third project, additive layer manufacturing, is being developed by the company as part of a clean technology strategy. This technology has also been developed in the supply chain, with the case company primarily relying on suppliers to mature the technology. It is considered a clean technology because typical manufacturing techniques take a large chunk of material and machine away up to 90% creating a great deal of waste during the process. ALM, on the hand, uses laser technology on a bed of metal powder to create layer after layer of the component. In the end a component is "3-D printed" into existence reducing waste to around 5%. Finally, ALM is seen as a clean technology because it has the potential to disrupt the entire manufacturing industry and is considered by many to be "game-changing" technology leading to relatively high levels of technological uncertainty.

### *3.2 Triadic Case Study Design*

The case study extends past the boundaries of the case company to include an upstream supplier and downstream customer. In so doing, the case study format becomes a triadic, or three-way, design. A triad is a network arrangement that allows the researcher to study how a node affects another node (e.g. A affecting B or C) and a link affects another link (e.g. AB affecting AC or BC) (Choi and Wu, 2009). The triadic case design allows the researcher to understand which actors are driving, supporting or hindering the embedding of product stewardship and clean technology strategies in the NPD process. The supplier is a small additive manufacturing company comprised of fifty employees. The paper examines how the supplier and case company have worked together over the past five years on the development of the ALM technology. The customer is a large multinational company that is interested in purchasing both carbon composite and additive manufactured components from the case company. As titanium aluminide was developed internally at the case study company it was only discussed with case company interviewees and focus group members

### *3.2 Data Collection Methods*

To improve reliability this paper uses a triangulation data collection method including semi-structured interviews, focus groups and secondary data as advocated by Yin (2009). A total of 42 semi-structured interviews were conducted at the case study company, the supplier and customer. In addition, eight focus groups were conducted to limit confirmation bias by providing a check on the interview findings and ensuring interviewees were not telling the researchers “what they want to hear”. Secondary objective data provided a further check allowing the researchers to confirm or reject statements given during interviews and focus groups. This data included company procedures and protocols, supplier contracts, supplier management document and strategy documents. Data collection stopped when a point of

theoretical saturation was reached, or when additional data did not provide new information or understanding (Eisenhardt, 1989; Lee, 1999).

### *3.3 Sampling Technique*

A snowball sampling technique to select each interviewee was used. This sampling method was selected due to the highly sensitive and confidential nature of the data and the reluctance of the case company employees, suppliers and customers to take part when unfamiliar with the researcher and the research project (Taylor and Bogdan, 1998). Snowball sampling allowed the researchers to use the initial contact as a gateway to gain access and to inform subsequent interviewees of the nature of the project and provide reassurance of the steps taken to maintain confidentiality.

### *3.4 Data Analysis Techniques*

Data was analysed using thematic analysis techniques. With thematic analysis the researcher produces a list of themes and codes from the textual data (King, 2004). NVIVO 10 software was used to code the interview transcripts, focus group notes and secondary documentation. Using hierarchical coding groups of similar codes were clustered together to produce more general higher order codes, or themes. Themes provide a good overview of the general direction of the interview, while detailed lower order codes allow for a very fine distinction to be made within the case (King, 2004).

## **4 Findings**

After rigorous analysis of the data it was apparent that two overarching themes emerged we label these: Barriers and Enablers, because they appear to be either enhancing or restricting the firm's ability to move towards the high sustainability goals of product

stewardship and/or clean technology. Under the Barriers category sit the sub-themes of: technological uncertainty, cost minimization using sustainability, supplier relationships and issues concerning intellectual property. Under the Enablers category are the sub-themes of: strategic approach to sustainability, supplier collaboration and intellectual property sharing. We will now discuss each of these main and sub-themes in turn.

#### **4.1 Barriers to embedding product stewardship and clean technology strategies in the NPD cycle**

##### *4.1.1 – Technological Uncertainty*

Technological uncertainty emerged as the first barrier to embedding product stewardship and clean technology strategies in the NPD cycle. The clean technology project, additive layer manufacturing, was found to be the most adversely affected by technological uncertainty. The product stewardship project, carbon composites, was less affected but some impact was evident. Technological uncertainty was not found to have a noticeable effect on the development of titanium aluminide. Table 1 provides a summary of how technological uncertainty was seen by interviewees to affect the ALM and carbon composite projects.

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ALM was seen by a majority of interviewees to be a game-changing technology due to its ability to open up a new design space, utilize novel materials and revolutionize the manufacture of components. Interviewees explained the case company developed ALM in the supply chain because it had insufficient in-house knowledge or capabilities in the technology. So, despite ALM being seen as a strategically important technology to the company, it still felt external partners were better positioned to mature the technology. This suggests that

uncertainty around the technology was a primary motivating factor in outsourcing development. The novelty of ALM to the aerospace industry also meant few suppliers existed in the market with sufficient knowledge, capacity and capabilities to develop components to the high specification required by the case company. Although many suppliers had developed prototypes and components for other industries such as medical and automotive few had experience delivering to the stringent requirements of the aerospace industry. One interviewee explains: *“the supplier maturity overall was very very low. And the knowledge to understand how it applies to aerospace isn’t there....these bureau suppliers have been born out of rapid prototyping making parts for all sorts of different industries....that aerospace rigour is very very different”*. Another four interviewees stated supplier knowledge around ALM is very limited which creates uncertainty as single points of failure exist in the supply chain: *“knowledge and maturity is in pockets and enclaves. You think about a business continuity point of view, if you have a single point of knowledge and a single point of potential failure, you haven’t got business continuity.”*

High degrees of technological uncertainty also affected the extended supply chain of machines and powders. Again, the novelty of the technology to the aerospace industry and rigorous requirements of the case company meant few raw material and machine providers exist which could meet specifications. As one interviewee explains: *“The whole supply chain doesn’t exist at the moment.... there’s issues around powder cost and clearly, you need to have machines that meet the rate and the capability that you need. And at the moment there aren’t many places you’d go to say ‘could you start making me a thousand components in a year?’ Where would you go?”*

Another interesting finding was that the competition was very aggressive in purchasing promising ALM suppliers in the early stages of development. One such example is when a large multi-national purchased an ALM machine provider just as the supplier began to

actively pursue the additive manufacture of metal components. This gave the competitor an edge over the case company in terms of capacity whilst blocking the case company from a significant source of ALM machines. One focus group member felt the competition were quick to acquire suppliers and this activity was often unforeseen by the case company.

Technological uncertainty also played an important role in the development of carbon composites. The case company decided to develop the technology using a joint venture with a supplier who had expertise in the material from different sectors. Again, even though carbon composites were seen to be a strategically important technology, the case study company sought to reduce technological uncertainty by tapping the experience of its supply base. Four of the interviewees felt the joint venture sped up carbon composite development in the early stages. One interviewee explained why: *The joint venture has its advantages because you're bringing ongoing knowledge and expertise from [The supplier] in to that JV.* This view was further supported by another interviewee who stressed how this collaboration allowed the knowledge and experience of the supplier to spill over to the case company: *"I think in the JV we had more expertise at our disposal if we wanted it, people who .... worked for [the supplier] who were really experienced, long-term guys who could drop-in and help sort out a problem".*

#### *4.1.2 – A cost minimization approach to sustainability*

A cost minimization approach to sustainability emerged as the second barrier to embedding product stewardship and clean technology strategies in the NPD cycle. Twenty-eight interviewees believed cost reduction to be the main driver of environmental performance improvements in new technologies and/or products (see table 2). Interviewees explained how the case company constantly strove to improve fuel consumption of the product as this is the primary cost incurred by customers. Several interviewees stated that by improving fuel burn

the additional environmental benefits of reduced carbon dioxide and nitric oxide emissions were also realized. This cost minimization approach is explained by one interviewee: *“You can boil it down to being about how much fuel we burn. So ultimately, a load of our research is about getting our product more efficient and burning less fuel. That can be either because it's lighter, it's a better architecture, the components.... and that of course has a pound note and economic benefit for the airlines, so ultimately a big chunk of what we're doing in R&T is fundamentally about fuel burn and therefore the environment”* Legislation was cited by twenty-five interviewees alongside cost as playing an important role in the case company's push for environmental performance improvements, but with cost often being the primary driver.

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Customer interviewees also saw cost reduction as the primary driver behind pursuing environmental performance improvements in new technologies. One customer interviewee explains how legislation is an important but secondary driver to cost minimization at his company: *“I think the main driver is probably cost....we comply with legislation as it comes out, but.... the main driver for us in terms of production is whether we can actually produce something cheaper and faster with a quicker turn-around”*.

Similarly, the supplier interviewees saw cost as the main factor that drove sustainability at their company. One supplier interviewee summarizes the responses given: *“It [sustainability] is driven by cost, customer, legislation. So the customer may be driven first by legislation. They are told to reduce emissions on the products of their cars or aircraft or whatever. Our customer, they're not driven by some altruistic desire to reduce emissions. They're driven by*

*the fact that EU legislation is put in...Of course, from a marketing point of view they will then say 'yes, we're driven by environmental factors'.*

#### 4.1.3 Supplier Relationships

The case company's approach to supplier relationships emerged as the third barrier. Seven interviewees felt the case study company lacked collaborative supplier relationships, in particular with suppliers of strategic components or technologies (see table 3). One focus group member explained the company primarily has make to print (white box) suppliers and some design-make (black box) suppliers. However, he stated there were very few instances of formalized "grey box" supplier collaborations.

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One interviewee explained how collaborative relationships are very limited in the company due to cost pressures: *"The partners you work with, they've got to make their crust as well. They're trying to maximise their margin, we're trying to maximise our margin. It's just become a tug-of-war. On all our supply chain, we're on a major drive to push cost down....and the SMEs are no different from anybody else really. We're being pushed by our customers, the competitive climate is tight. We've got to keep driving cost down"*

As part of secondary data collection the researchers reviewed the agreement in place between the case company and the supplier case company. Within the agreement it states that: "The Parties shall jointly pursue cost reduction opportunities for the duration of this Agreement and will reflect the achievements of such opportunities in price reductions to the case company". The researchers also reviewed the generic supplier agreement template which states: "The Supplier will, at all times during the Term, conduct cost reduction activities. The



case company may deploy its personnel to work with the Supplier on cost reduction activities and the Supplier agrees to fully engage and cooperate to develop and implement cost reduction activities. The output of all such cost reduction activities will be reflected in a reduced price for the Deliverables”. This shows how the case company pursues cost reductions across the board regardless of whether the supplier is providing a strategically important product or a generic commodity.

One interviewee explains how purchasing tends to put cost reduction pressures on its supply base regardless of the strategic importance of the component. *“There are a number of conferences I’ve been to where all the suppliers are told ‘you’ve done a great job on doing this, but we now need you to go and take 10%, 5% cost out of your product’ and it was just a flat requirement... rather than...working with them and saying ‘well, how together can we develop a lower cost part?... God, it’s frustrating sometimes when you see that happening”*.

Two interviewees stated these cost pressures mean suppliers have little profit left to reinvest in Research and Development. One interviewee explains the difficulty this creates: *“a supplier will think-‘why should I bother developing anything for [the case company] when you’re actually just going to screw me on price and I’m never going to get that investment back?’ The other thing is, if you are taking margin-away from suppliers, their ability to invest in to R&D is obviously reduced. And that’s a difficult balance because obviously, we need to make sure that our supply chain’s competitive, but at the same time we’ve got to recognise that they need money to invest, and squaring that circle is sometimes very difficult”*.

Another issue as seen by nine interviewees was that suppliers were not involved early enough in the NPD process. One interviewee explains this view: *“I don’t think we’re good at leveraging our supply chain in terms of new technology, partly because we leave it too late. So the design is pretty much fixed before we start earnestly talking to suppliers”*. One focus group member explained the case company tended to give detailed instruction of product

design and the supplier had to adhere to this specification, however little help was given if the supply couldn't meet these stringent guidelines. Finally, one interviewee felt the case company was reluctant to commit to a longer term spend with suppliers. He explains the issues this creates: *[The case company] are very good at saying 'well, we're not guaranteeing you anything. We're just looking and we'd like three different suppliers to do this and we'd like options and we'd like to use the cheapest. But a supplier, would probably say, 'well, there's non-guaranteed revenue here. I'm not going to spend all of my own R&T [Research and Technology] money developing something you want where I might not get anything back for it'.*

#### 4.1.4 Intellectual Property Protection

Ownership of intellectual property emerged as a significant barrier to the involvement of suppliers in product stewardship and clean technology strategies. Seventeen interviewees highlighted IP ownership as creating issues in supplier relationship and the longer term development of the technology (see table 4). Seven interviewees felt tension arose because the case company wants to own all foreground IP, which is all the newly created IP generated between the two parties during the NPD project. Interviewees explained the case company is trying to maintain “executable choice” which means the case company is not tied to one particular supplier during the development and commercialisation of the technology.

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In fact, one interviewee explained that suppliers were not involved early in the NPD process because of the issue of IP ownership: *“That is something I think we're very weak on, we're not so good at bringing suppliers early... we get tied up in this IP issue, we don't know how to bring them in to create joint IP...it's a balance, as soon as you bring a supplier in, the more*

*learning you get earlier, which is good, but the more you constrain yourself to lock yourself to one supplier, which may hurt you later. So it's managing that trade-off, and we tend to default with 'okay, we won't bring them in because of those risks'.*

During secondary data analysis the researchers reviewed the agreement in place between the case company and the supplier case company. This agreement states that “All right and title in and to any and all Foreground IP will vest in [the case company], and the Supplier hereby assigns absolutely with full title guarantee the Foreground IP and shall where required procure the assignment of the Foreground IP to [the case company]” Interestingly, a supplier interviewee was quick to point out his company would not enter into any future contractual agreements where the case company owned all foreground IP. He explains: “*We have signed IP agreements already, but I think where there is a real risk with the IP side of things... on the one hand, to be too lax from [the case company's] point of view and end up with us owning IP that stops them from doing something. On the other hand, by being too tight with it, I'll end up not signing the agreement because, whatever we do, [the case company] owns it. I'm not going to sign that*”.

The next section draws on the opinions of interviewees and focus group members to suggest steps the case company can take to smooth the process of supplier involvement in embedding product stewardship and clean technology strategies in the NPD cycle.

## 4.2 Enablers of supplier involvement in product stewardship and clean technology strategies

### 4.2.1 Strategic Approach to Sustainability

Although cost and legislation were seen as the primary drivers of sustainability at the case company, ten interviewees said the customer's sustainability agenda was gaining importance (see table 5 below). These opinions suggest the case company is beginning to move past cost reduction and compliance towards seeing sustainability as a way to secure new business and achieve competitive advantage. One senior supply chain interviewee explained how sustainability is rising up the agenda for their airframe customers: *"We've actually just been with one customer last week... who are really making a very strong play on sustainability for their products and will be requiring all their suppliers to be very very clear about the sustainability of their products down to a very low level of detail, so that's becoming all the more important. It will flow through to suppliers. Our customer...they're flowing it down to us and they will require us to demonstrate our supply chain"*.

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Another nine interviewees explained how the strategy formulation process at the focal firm has changed over the past three years to become much more customer focused. One interviewee sums up the situation: *"In the past, we'd probably be more 'technology could deliver us this – let's do it!' Now we're much more, right, what does the market need?' to pull the technology through rather than push it. Looking over a sort of twenty year period, what are they going to be requiring? Therefore, what capabilities do we need to meet those requirements? Therefore, what technologies do we need to meet those capabilities that then meet those requirements?"* Seven interviewees felt the competition was driving the focal firm

to be more sustainable. One interviewee explains the competitive environment currently and how the firm can use sustainability as an order-winner and tool to achieve competitive advantage: *“the competitive environment we live in forces us to push pretty hard on all of those environmental requirements because they are differentiators. NOx, carbon monoxide, hydrocarbons, smoke, etcetera. If we are failing to match our competitors in any significant sense in any of those then we’re going to struggle and lose business. So I think the marketplace actually keeps us pretty focussed as well”*.

In terms of product stewardship, one respondent explained how the case company is now considering the whole-life cycle of the product during design: *“We visit the whole life-cycle.... we look at how we dispose of products. Effectively at the design stage, you're dealing much more with the building blocks. The commodity strategies will envisage how we reuse material, so we revert the raw material from manufacturing shops, we revert the material from end of use. So at the product level it is not obvious, but if you drill down in deeper levels, in terms of the commodity strategy, you should see the sustainability element coming in to that level”*. Another employee explained how end of life is growing in importance during product design: *“it's growing. When I was designing components, it was many years ago and it was not as mature as we are now...the whole designing for manufacture, designing for repair, those are things that have now happened to ensure that you're not creating a wasteful process further down the line and that the components are possible to repair, rather than being thrown away.”*

Seventeen interviewees expressed concern that the case study company’s senior management team did not maintain focus on strategic technologies, materials or components in the early stages of development. This finding was found to be particularly true for ALM, carbon composites and Titanium Aluminide. Lack of focus meant these technologies were started,

stopped and re-started a number of times delaying overall development times. In realization of this fact, the executive team implemented what it calls its “top eleven” technologies in 2013. These are the case company’s key technologies seen as being critical to achieving and sustaining competitive advantage. ALM, Carbon Composites and Titanium Aluminide are three of the eleven technologies. Several interviewees pointed out that once these three technologies were nominated as top 11 technologies their rate of development sped up dramatically. Six interviewees explained that the introduction of integrated project teams (IPTs), comprised of a technology champion and dedicated experts from various parts of the business, have also been critical in increasing the pace of development of the three technologies. One supplier interviewee explained the change that occurred when the Integrated Project Team was put in place for ALM: *“Once they came on-board and we started having that dialogue, it kind of went backwards and then got momentum forwards very very quickly. they’ve come up with some good documentation. What the strategy is, how it fits together, it now gives them direction ...so I think it’s been really worthwhile from their point of view”*

#### 4.2.2 Supplier Collaboration

Both the case company and supplier interviewees discussed several initiatives that could be pursued to better enable supplier involvement in product stewardship and clean technology (see table 6)

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Since 2013, the case company has recognized the importance of moving towards more collaborative supplier relationships. A Supply Chain Collaboration Manager has recently

been appointed to improve relationships with strategic suppliers. This individual explains the shift in company culture that is currently taking place: *“It has really put a stake in the ground to our top 135 suppliers that we want to listen, we want to understand and work together collaboratively, rather than the, ‘you’ll do as I say and by the way, we want 5% cost down. So trying to say, how can we work together to get cost out? But also, how can we work together to innovate? So that’s really been a sea-change, and I think that’s sort of linked to our culture change that we’re going through at [the company] as well”*.

One interviewee felt that supplier collaboration could be improved through investing in the capability development of suppliers of strategically important technologies such as ALM: *“if you look at additive layer, you’ve got suppliers who understand the technology but who haven’t yet really built a viable commercial vehicle for the exploitation of that. Sometimes I think that’s where we could do a little bit more to help, particularly in real novel technologies, I think if we could get better collaboration with ground-breaking small companies and support them and get them working and help them grow...I think there’s a win-win there”*.

Another interviewee explained how the cost reduction pressures applied across the supply base can be counterproductive. He outlined the steps he took to collaborate with suppliers in a joint cost savings initiative: *“[the project] I was involved in is not so much technology-driven but more, how do we get cost down and how do we get cycle time reduction? And we came up with ideas, suppliers came up with loads of ideas and we probably implemented about 60-70% and it drove out huge swathes of cost and lead time. Sometimes these things don’t work because [the case company] is not prepared to share anything back in terms of benefit. We want to take all the benefit. We go for a price reduction typically, rather than margin retention by both parties”*. One focus group member believed the emphasis should be

on intelligent research and development where the company looks at the end game of the technology and strategic supplier are exempt from cost reduction targets.

Two interviewees stressed the need to create a longer term spend that suppliers can rely on. Using an example from his past experience one interviewee explains how this process could work in practice *“What we were trying to do here was a two-way approach, they were trying to tell us a bit more about the capabilities of the technology, what the roadmap for development of it was. We were then trying to match that to a portfolio of parts that we could make using that technology. That then does a number of things. It creates a spend that we could start to say 'is this going to be a significant technology for the company or not?' and then we can start to align resource to developing it...we will open up a market of... forty million a year that you [the supplier] then play in...you have to follow through in terms of what you say you're going to do, otherwise you get the supplier to invest with no work coming”*.

A supplier interview explained that with longer term guarantees the supplier could secure financial backing to invest in developing their technological capabilities: *“if we get some warning, and significant commitment, in other words some sort of cast-iron guarantees that we're going to get the work, then sure, we can change the company to match. I'll move an awful lot of things around to make sure that we can meet a demand profile. And if we can be even more secure in terms of a medium- to long-term profile, that we can work closely with [the case company] on, then that would enable me to multiply the capacity by a factor of 5 or 10 within a short space of time....I've got no problem with it but I'm not going to do it just on the off-chance that something might happen”*.



Two supplier interviewees stressed collaboration should start during design and stated the supplier is willing to provide training courses to engineers and designers at the case company. One supplier interviewee explained the new direction that the supplier and case company were moving in: *“Currently, to a large extent they come to us with a design and we manufacture it....we are working on a project now where the initial thing now is that we manufacture to a specific design, but they will then want us to look at how we can optimise that design for the process ....the idea is to do a like-for-like component and then look at how we can optimise it... And with that, we were going to talk to designers directly...I think, the best way for [the case company] to move forward is to do like for like and prove that it will outperform what they’re currently using. Until they’ve done that they can’t move forward”*.

#### 4.2.3 Intellectual Property Sharing

Thirteen interviewees stressed the need for a very clear IP ownership strategy prior to engaging suppliers in NPD projects (see table 7.0). One interviewee suggests the use of supplier conferences and workshops during the early product development stages can help address the IP ownership issue: *“Key to a lot of overcoming IP problems later on is, when we initially launch programmes, is getting workshops, suppliers sessions, set up specifically to be clear on who owns foreground IP, what the background IP is, what the strategy is moving forward. You know, the strategy might be to patent. The strategy might be to publish. It’s actually being very clear early on what the overall intellectual property strategy is moving forward”*.

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Three interviewees stressed that if a collaborative relationship were in place then IP could be shared. Another interviewee stressed the importance of being clear on what part of the

technology or process is important to the case company and only protecting that: *“Owning IP is if you like, a sledgehammer to crack a nut. There are many other ways that you can utilise IP without necessarily owning it. Now, whether that’s a royalty-free license, whether it be that you have IP or a supplier has IP that they agree only to use with [the case company] in a particular market segment but they’re free to do it in medical where we’re not competing ...so you need to break it down in to its constituent parts and say ‘what are the bits that we really want to focus on?’*

Suggestions were given by one supplier interviewee on ways that the case company could better approach the IP ownership issue. He suggests balancing the case company’s desire to have executable choice against the suppliers desire to keep what they create through having licensing mechanisms within the supplier contract: *I think when it comes to very specific designs, then clearly we have to understand what is critical for [the case company] to retain in their IP... If we come up with a bespoke way of building something which is part of our background IP, that’s where the licensing would take place. if that [IP] then is shared with another company, then we should get some future benefit.*

## **5. Discussion**

Four themes emerged as barriers to the involvement of suppliers in product stewardship and clean technology strategies; technological uncertainty, a cost minimization approach to sustainability, supplier relationships and intellectual property. Technological uncertainty was found to affect whether the firm developed the technology in-house or in the supply chain. When technological uncertainty was low, as with titanium aluminide, the technology was developed in-house with informal supplier input (white-box involvement). When moderate degrees were present, as in the case of carbon composites, the case company formed a collaborative joint venture to benefit from the supplier’s knowledge and expertise (“grey

box” involvement). When technological uncertainty was high, the case company put even more reliance on the supply chain to develop the technology, particularly relying on small start-up firms with existing capabilities in ALM (“black box” involvement). The novelty of ALM to the aerospace industry also meant only one or two suppliers had the capacity and capabilities to machine components to the specifications required by the case company. This created greater degrees of technological uncertainty as the case company had one or two points of failure in the raw material supply chain.

The second barrier to supplier involvement was a cost minimization approach to sustainability. In the main, interviewees at the case company, supplier and customer saw sustainability as a cost and compliance exercise as opposed to achieving competitive advantage. The NRBV suggests competitive advantage can be achieved through competitive pre-emption that occurs when the firm gains preferred or exclusive access to important but limited resources (e.g. raw materials, location, productive capacity or customers) (Hart, 1995). A strategy of competitive pre-emption could prove particularly fruitful in the case of ALM. The case company could look to secure sole access to raw material powders and machine capacity therefore blocking competitor entry. The NRBV also suggest competitive advantage can be gained through claiming reputation “space” in terms of corporate environmental performance (ibid). This means being seen by customer’s and end users as a brand of choice for the environment and using this brand image as a selling tool to secure new business.

Interestingly, several interviewees in customer facing positions highlighted how airlines and airframe customers were moving sustainability up the agenda and would expect the case company to demonstrate environmental performance improvements in its wider supply chain. The case company’s recent focus on designing products for the environment including whole life analysis and extended component life could help in securing new business. The carbon

composite case was particularly telling in that it showed how supplier involvement right at the design stage could drive product stewardship strategies forward. Improved strategic support through the nomination of the “top 11” technologies was also found to be a significant enabler of advancing the development of all three projects. This shows that with a strategic vision in place companies can drive the development of technologies that improve environmental performance.

The third barrier to emerge was the nature of the supplier relationships. Several interviewees felt that supplier relationships needed to be more collaborative and that suppliers only tended to be involved in NPD projects after a product specification was in place. In fact, a focus group member said the case company tended toward white box or black box supplier involvement with few supplier grey box relationships. Yet, the example of the carbon composites joint venture showed that grey box relationships were possible and even desirable. Furthermore, this project showed that early supplier involvement in product stewardship strategies allowed the knowledge and expertise of the supplier to spill-over to the case company speeding up development times and reducing technological uncertainty. The recent introduction of a supplier collaboration manager tasked with improving supplier relationships also showed promise. Moreover, supplier interviews highlighted how technology champions and integrated project teams both improved relationships and drove technology development forward. The case company, having recognized the importance of supplier collaboration, seemed well placed to see improvements in future product stewardship and clean technology development programmes

The fourth theme to emerge as a barrier was intellectual property sharing. One focus group member stated that his firm's desire to own foreground IP stopped several supplier agreements from even getting off the ground. Yet, other interviewees felt if collaborative supplier relationships were in place then IP could be shared. Importantly, these interviewees stressed

the case company had to be clear early in the project what IP was strategically important and only look to own that aspect. They explained that often the supplier and the case company had different strategic priorities for IP and conflicts were unnecessarily created by the case company's desire to own all foreground IP.

### *5.1 Managerial Decision Matrix*

During the research project the author and members of the project's steering committee developed a matrix to help managers decide which type of supplier relationship to pursue when embarking on pollution prevention, product stewardship or clean technology strategies. The matrix is designed to provide managers with a more strategic approach to sustainability. It suggests that different types of supplier relationships are required depending on the degree of technological uncertainty and the supplier's environmental design and development capabilities (see the x and y axis). For example, the matrix suggests that if the supplier has a sustainability strategy in place, a strong ability to manage the environmental performance of sub-tier suppliers and is committed to reducing waste during design and manufacture then a "black box" supplier relationship should be pursued. In this instance the supplier would take responsibility for the majority of technology development and the buyer would only own the IP that it deems strategically important. In contrast, if the supplier does not have a sustainability strategy in place, does not proactively manage sub-tier suppliers and has limited design for environment capabilities then the firm should look for a make-to-print or white box relationship. It should be stressed however that even white box suppliers should be compliant with current legislation and not pose a risk to the firm in terms of irresponsible environmental behaviour. The matrix assumes the decision to outsource technology development has already been made.

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## **6. Conclusion**

### *6.1 Theoretical Implications*

Theoretically, the paper explores the role that technological uncertainty plays in product stewardship and clean technology strategies. The findings suggest that companies will outsource design and development of new technologies when technological uncertainty is moderate to high. Specifically, when a company recognizes it lacks the necessary design and development capabilities in-house it will engage with suppliers to fill this gap in knowledge and experience. Supplier involvement then seems to be a strategy to mitigate technological uncertainty when embedding product stewardship and clean technology strategies in the NPD cycle. Furthermore, the paper makes a contribution to the SI- NPD literature by moving beyond an understanding of the economic benefits of supplier involvement to understanding how environmental benefits can be achieved. The paper has stressed the importance of forming collaborative relationships with strategic suppliers, where intellectual property is shared, when embarking on product stewardship and clean technology strategies.

### *6.2 Managerial Implications*

In terms of a practical contribution the paper advances a decision making matrix to assist managers in determining the most appropriate type of supplier relationship to pursue when utilizing product stewardship and clean technology strategies. The tool is designed to allow managers to approach environmentally responsible NPD projects more strategically, recognizing that different types of supplier relationships are appropriate in different types of situations. The matrix asserts suppliers should only be involved in product design and

development if they have the requisite knowledge, capabilities and proactive approach to environmental management. Moreover, the matrix suggests that IP should not be shared in all instances but only when a collaborative supplier relationship is in place. The paper has also highlighted some of the key barriers and enablers of involving suppliers in product stewardship and clean technology strategies. By creating awareness of these factors managers can isolate and eliminate these barriers in their own operation whilst seeking out the enablers which smooth the process of supplier involvement,

### *6.3. Limitations and future research*

The research benefited from, but is also limited by, the single case study method. Using a single case format provided the depth of information needed to study this relatively new and unexplored area. However, the research is limited in that only the opinions of the case company employees, its supplier and customer have been collected. Further barriers or enablers will likely emerge if other companies or industries are studied. This then provides a fruitful area of future research. Specifically future researchers could investigate if the same or different factors emerge when study high technology firms in other industries, such as automotive or electronics. Other research avenues include looking at other triadic configurations, such as supplier-supplier-buyer triads and how these relationships influence product stewardship and clean technology strategies. Finally, researchers could look to other theories for insights into the phenomenon such as stakeholder theory (Freeman, 1984), or the knowledge based view (Grant, 1996). Stakeholder theory could help researchers understand the influence of other key stakeholders in product stewardship and clean technology strategies. The knowledge based view could look at the importance of knowledge exchange between buyer and supplier during new product development and if this process differs when developing environmentally responsible technologies.

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**TABLE 1****Technological uncertainty and the effect on product stewardship and clean technology strategies**

<b>Coded Response</b>	<b># of responses out of 42</b>
Supplier maturity is very low in ALM	3
Knowledge and maturity around ALM is in pockets and enclaves	4
There is a not a well-developed supply chain for ALM machines and powders	10
Limited number of capable powder suppliers creates risk for development of ALM	1
Competition have bought ALM capacity and capabilities	8
Decision to work with Suppliers on carbon composites was due to supplier having more robust capabilities and experience with tech	2
Joint Venture helped pace of Carbon Composite development early on	4

**TABLE 2****A Cost Minimization approach to Sustainability as a barrier to embedding product stewardship and clean technology strategies**

<b>Coded Response</b>	<b># of responses out of 42</b>
Cost reduction is the primary driver behind trying to improve environmental performance of new technologies/engines (case company interviewees)	28
Legislation plays an important role in improving environmental performance of new technologies/engines (case company interviewees)	25
Cost reduction is primary driver behind trying to improve environmental performance of new technologies/products (customer interviewee)	3
Legislation is secondary driver of environmental performance improvements (customer interviewee)	1
Cost minimization, legislative adherence and customer attraction are the main drivers of sustainability at supplier (supplier interviewee)	3

**TABLE 3**

**Supplier relationships as a barrier to embedding product stewardship and clean technology strategies in the NPD process**

Coded Response	# of responses out of 42
The case company needs more collaborative relationships with suppliers developing strategically important products	7
Purchasing too focused on finding lowest cost supplier	4
Cost reduction pressures on suppliers inhibits their ability to invest in R&D	2
Not enough resources for developing supplier capabilities for strategic technologies	7
Suppliers are not involved early enough in new technology development (Design stage)	9
Suppliers are involved in development only after technology specification is in place	4
The case company is reluctant to invest in developing capabilities of suppliers of promising new tech	2
The case company is unwilling to commit to longer term spend that suppliers can rely on (case company interviewee)	1

**TABLE 4**

**Intellectual property ownership as a barrier to embedding product stewardship and clean technology strategies in the NPD process**

Coded Response	# of responses out of 42
Ownership of IP creates issues in supplier relationships	17
The case company try to own all foreground IP in tech dev. projects with supplier	7
IP ownership creates issues when working with suppliers to develop ALM technologies	5
The supplier case company is unwilling to sign an agreement where the case company owns all forward IP (supplier interviewee)	1

**TABLE 5****Recommendations for taking a more strategic approach to sustainability**

Coded Response	# of responses out of 42
The customer's sustainability agenda plays an important role in improving the environmental performance of new technologies/engines	10
Customer requirements now drive strategy process	9
Competitor activities play an important role in improving the environmental performance of new technologies/engines	7
End of life is now considered during product design	11
Reducing Rare Earths is a concern during the selection of new materials	9
The Supply Chain is now designed with the environment in mind	3
The case company is investing in technologies that prolongs the life of components	3
The case company need to maintain strategic focus on key technologies	17
Increased top level support has sped up development of ALM	3
Increased top level support has sped up development of Carbon composites	1
Integrated Project Teams (IPTs) have sped up rate of technology development	6
Focus given by ALM IPT team has sped up development (supplier interviewee)	1

**TABLE 6****Recommendations for improving supplier collaboration on product stewardship and clean technology strategies**

Coded Response	# of responses out of 42
The case company now recognizes the importance of being more collaborative with suppliers	5
The case company needs to create a spend for strategically important tech that suppliers can rely on (case company employee)	1
If the supplier had longer term guarantee of business could work with the case company to increase capacity to meet their needs (supplier interviewee)	1
The supplier is now looking at how to assist the case company in optimizing design of new components (supplier interviewee)	1
By consulting on the case company's design the supplier could challenge established ways of thinking (supplier interviewee)	1
The supplier has the ability to improve environmental performance of technology by being involved in product design (supplier interviewee)	2

**TABLE 7**  
**Recommendations for Intellectual Property Sharing**

Coded Response	# of responses out of 42
Need clear IP ownership strategy early on in supplier relationship (case company interviewee)	13
If collaborative relationship in place IP can be owned jointly with suppliers (case company interviewee)	3
The case company need to specify what aspect of technology is strategically important and protect IP accordingly (case company interviewee)	2
The case company needs to recognize there are many ways to utilise IP without necessarily owning it (case company interviewee)	1
IP sharing agreement should balance the case company's ability to use other suppliers and the supplier's ability to own what it creates (supplier interviewee)	1
Need licensing mechanism for joint IP if the case company want to share with other supplier so supplier can see future benefit (supplier interviewee)	1

**FIGURE 1**

**Supplier Involvement in Product Stewardship and Clean Technology Strategies-  
Decision Matrix**

<p align="center">Technological Uncertainty</p> <p align="center">↑</p> <p align="center">High</p>	<p><b>White Box Clean Tech Development</b></p> <ul style="list-style-type: none"> <li>• Informal supplier integration</li> <li>• Clean tech development and design led by buyer</li> <li>• buyer “consults” with supplier on design</li> <li>• Foreground IP owned by buyer</li> </ul>	<p><b>Grey Box Clean Tech Development</b></p> <ul style="list-style-type: none"> <li>• Formalized supplier integration.</li> <li>• Clean Tech is jointly designed and developed between buyer and supplier</li> <li>• Foreground IP is shared between buyer and supplier</li> </ul>	<p><b>Black Box Clean Tech Development</b></p> <ul style="list-style-type: none"> <li>• Clean Tech design is primarily supplier driven, based on buyer’s performance specifications</li> <li>• Forward IP is shared between buyer and supplier</li> <li>• Design/make supplier</li> </ul>
	<p><b>White Box Product Stewardship</b></p> <ul style="list-style-type: none"> <li>• Informal supplier integration</li> <li>• Product is designed by buyer for the environment</li> <li>• RR consults supplier on design for environment including life cycle assessment and end of life</li> <li>• Foreground IP owned by buyer</li> </ul>	<p><b>Grey Box Product Stewardship</b></p> <ul style="list-style-type: none"> <li>• Formalized supplier integration.</li> <li>• Product is designed jointly by RR and supplier for the environment</li> <li>• Life cycle analysis including end of life conducted jointly between buyer and supplier</li> </ul>	<p><b>Black Box Product Stewardship</b></p> <ul style="list-style-type: none"> <li>• Supplier leads designing product for environment initiative and life cycle assessment</li> <li>• Product is designed by supplier with end of life in mind</li> <li>• Forward IP is shared between buyer and supplier</li> </ul>
	<p><b>White Box Pollution Prevention</b></p> <ul style="list-style-type: none"> <li>• Cost focused/higher volume suppliers</li> <li>• buyer monitor’s supplier environmental performance to encourage pollution prevention strategies and legislative compliance</li> <li>• Foreground IP owned by buyer</li> </ul>	<p><b>Grey Box Pollution Prevention</b></p> <ul style="list-style-type: none"> <li>• Formalized supplier integration</li> <li>• Buyer and supplier work jointly to implement pollution prevention strategies at suppliers and in 2<sup>nd</sup> and 3<sup>rd</sup> tiers</li> <li>• Cost savings from Pollution prevention strategies shared between buyer and supplier</li> </ul>	<p><b>Black Box Pollution Prevention</b></p> <ul style="list-style-type: none"> <li>• Supplier designs product to prevent pollution throughout sourcing, manufacturing and distribution process</li> <li>• Pollution prevention driven by supplier internally and in 2<sup>nd</sup> and 3<sup>rd</sup> tiers-cost savings shared</li> <li>• Forward IP is shared between buyer and supplier</li> </ul>

Low High

Supplier’s environmental design and development capabilities